or permanent base in southern California to give service on late fall fires common in that part of the State.

The unit will be operated for an experimental period of two fire seasons, the mobile equipment being supplied by the United States Forest Service, the operating expenses being paid by the California State Division of Forestry and the operating personnel and radio and meteorological equipment being supplied by the United States Weather Bureau.

If this novel plan is successful, and no insurmountable obstacles are now apparent, it is probable that three such units will be operated in California, one each in the northern, central, and southern parts of the State. The applicability of this plan to other forested areas in the far West is evident, since the weather data as broadcast from station NPG, on the reception of which the plan depends for success, can be copied almost anywhere west of the Mississippi. The fire agencies of British Columbia are much interested in the working out of this plan, and if successful in this State, consider it desirable to adopt it for their region, equipping launches instead of automobile trucks.

This plan will be on trial during the next two fire seasons in California. Past experience with this system on large going fires shows the plan to have much promise. We have reason to believe that successful operation of the system will be of far-reaching importance and application to organized fire protection work.

THE RECORD OF EVAPORATION STATIONS IN CALIFORNIA

551.573 (794)

By ERNEST E. EKLUND

[Weather Bureau Office, San Francisco, Calif., June 21, 1929]

Of the various climatic factors that have always an important, and sometimes predominant, influence on the economic development of a nation, state, county, or city, evaporation is one of more than academic interest throughout the semiarid Southwest, and particularly in California. Here the development of intensive farming and of hydroelectric power is dependent upon an average seasonal precipitation of approximately 25 inches, occurring during a few winter months. The snow pack that accumulates in the higher mountains during the winter is equivalent to an immense reservoir that keeps many streams flowing through all or part of the practically rainless summer, and in addition many huge reservoirs have been constructed to supply water for civic uses, for operating hydroelectric power plants and for irrigating many thousands of acres of farming land. A large portion of the water impounded, and of that distributed over the land in irrigation, is lost by evaporation. For this reason the question of evaporation becomes of considerable importance in the economic development of California.

The first evaporation measurements made in California, of which we have a record, were begun in 1881 at Kingsburg by the State department of engineering, but the first measurements of evaporation undertaken by the Weather Bureau were those made 20 years ago at Salton Sea and at auxiliary stations. It was not until 1918 that stations were established on a permanent basis with the standard class A equipment, now in use. At that time, records were being made at Lake Tahoe, using a floating pan, but in 1918 three stations were established, using land pans according to the present Weather Bureau standard. Two of these stations have been in operation ever since; one was closed of necessity in 1923. In 1924 and in 1925, two additional stations were established, making five stations cooperating with the Weather Bureau at the present time.

More than the usual number of requests for evaporation data were recently received at the San Francisco Weather Bureau Office and, as it was known that some evaporation records had been made or were being made in California without the cooperation of the Weather Bureau, efforts were made to learn what additional records might be available. A card was mailed to all California addresses that received Climatological Data—California Section. The card read: "The Weather Bureau is desirous of obtaining information relative to evaporation measurements in California that have been made, or are now being made, without the cooperation of the Weather Bureau. If you know of any such evaporation records, kindly give the information requested in the blank spaces below, and mail this card which requires no postage." The blank spaces were for the names and addresses of the persons making and reporting the observations. The response was immediate and gratifying. Many of the returned cards related to evaporation records, but the majority offered the use of other kinds of records or reported "no records known." The cards were followed up by circular letters and questionnaires addressed to the persons who were reported as having made evaporation measurements.

From the information thus obtained, a table has been compiled, the stations being arranged approximately in geographical order from north to south. In the table are included a few stations that are beyond the borders of the State but which may be considered as having the same climatic characteristics as the adjacent portions of California. The table is known to be incomplete but contains some information about most of the evaporation records that have been made in California. Unless otherwise stated, the evaporation was measured from fresh water. No attempt has been made to collect the actual records, for to assemble them in a manner that would render them useful would be practically impossible. Any attempt to correlate all of them would be hopeless, due to the great dissimilarity of equipment and methods and, in some cases, to the lack of specific information as to the conditions under which the measurements were made. A map is also presented (not reproduced), on which the stations are numbered as in the table, but all records made in any given locality are listed under one number. It is interesting to note on the map that the stations are most numerous in those sections of California where irrigation and power projects have reached their highest development; also that they are numerous in the extreme southern portion where precipitation is comparatively light, and totally lacking in northwestern California where precipitation is heaviest.

Why have so many evaporation measurements been made in California? The factors determining evaporation from free water surfaces are generally agreed upon by physicists, meteorologists, and engineers but, despite the fact that the laws of evaporation have been investigated for centuries, a satisfactory method for computing the evaporation from a water surface already existing, or from such a surface to be created by constructing a reservoir, has been hard to find, and opinions still differ as to the proper method of measuring evaporation from a free water surface. Great variations in temperature, relative

humidity, wind movement, elevation, and other climatic influences are to be found in California, and many of the evaporation measurements in California have been made by hydraulic engineers in an effort to make proper allowance for evaporation losses from a reservoir to be constructed. In some cases the measurements have been made to determine whether the losses in a water system were due to evaporation from the reservoir or to other causes, such as seepage or pipe-line leaks. Also confronting the hydrologist are other problems wherein he must consider evaporation, whether it be from snow, fresh water, brine, moist soil, or vegetation. In the commercial production of certain chemicals from mineralized deposits or waters, evaporation is highly important, and some of the evaporation records in California have therefore been made by chemical engineers.

Another group of observations has been fostered by agricultural interests, for use in various problems relating to irrigation practice, the water requirements of crops and to plant pathology. A few experiments have been made by physicists searching for more knowledge of the laws of evaporation or attempting to correlate records obtained from dissimilar types of equipment. A notable example of work of this kind is to be found in the experiments conducted at the California Institute of Technology at Pasadena by Prof. N. W. Cummings and others. It is claimed that a method for computing evaporation from a large water surface was developed as a result of these experiments.

Thus far there has been little cooperation among the several interests concerned in the making of evaporation records. In general, where sufficient time could be allowed, each person requiring evaporation data has set out to obtain them by actual measurement. No doubt helpful data could have been found had one known where to look, but until now no attempt has been made even to list the records that have already been secured. In this way, it is believed the table and map that have been prepared will be found of value for reference purposes.

	Station	Records made by—	Duration		Equipment	Remarks
			From—	To—		
1	Klamath Falls, Oreg.	Calif.-Oregon Power Co.	August, 1921	Present	Floating pan, 22 by 42 inches, circular, submerged 13 inches.	Records at Office of U. S. Geological Survey, Medford, Oreg.
2	A. Canal, Klamath Falls, Oreg.	Reclamation Service	July, 1917	June, 1918	Floating pan, 10 inches by 4 feet, circular.	Original records at Office of Bureau Reclamation, Klamath Falls, of Oreg.
3	Adams Boat Landing, Oreg.	do	May, 1913	September, 1918	do	Do.
4	Lower Lost River Diversion Dam, Oreg.	do	February, 1924	November, 1925	Floating pan, 10 inches by 3 feet, circular, submerged 4 inches.	Do.
5	Clear Lake (Modoc County), Calif.	do	April, 1911	November, 1913	Floating pan	Do.
6	Coppocks	do	May, 1916	August, 1923	Floating pan, 10 inches by 4 feet, circular.	Do.
7	Yreka[1]	Forest Service	July 4, 1925	Oct. 10, 1925	Porous cup atmometer (distilled water).	Original records at office of Forest Service, Yreka, Calif.
8	Fall River Mills (near)	Pacific Gas & Electric Co. and Weather Bureau.	do	Present	Class A, Weather Bureau standard.	Published in Climatological Data—California section.
	do	do	do	do	Floating pan, 10 inches by 4 feet, circular.	Records at Weather Bureau Office, San Francisco, Calif.
9	Prattville	Great Western Power Co.	Aug. 1, 1924	do	Floating pan, 18 inches by 3 feet square, painted white.	Records private property.
	do	do	Aug. 6, 1924	do	Pan, 3 by 3 feet, circular, embedded in ground.	Do.
10	Big Meadows Dam	do	Aug. 13, 1924	do	Floating pan, 18 inches by 3 feet, square, painted white.	Do.
	do	do	Mar. 27, 1925	do	Pan 3 by 3 feet, circular, embedded in ground.	Do.
11	Butte Valley Dam	do	Aug. 1, 1924	do	Floating pan, 18 inches by 3 feet, square, painted white.	Do.
12	Chico	U. S. Department of Agriculture and University of California.	1904	1905	Tanks set in ground (moist soil)	Records summarized in Experiment Stations Bulletin No. 177.
13	Dodgeland	Dodge Land Co. and Weather Bureau.	Sept. 21, 1918	December, 1922	Class A, Weather Bureau standard.	Published in Climatological Data—California section.
14	Biggs	United States rice field station	1913 (April to October).	1925 (April to October).	Tank set in ground	Original records at United States rice field station, Biggs, Calif.
15	Norman (near)	University of California	1918	1919	Pan, 18 by 20 inches, circular	Records at division of irrigation, college of agriculture, Davis, Calif.
16	East Park Reservoir	Bureau of Reclamation	1911	1923	Floating pan, 10 inches by 4 feet, circular.	Records on file with Bureau of Reclamation.
17	Tahoe	Geological Survey and Reclamation Service.	1900	1906	Floating pan, 2 inches by 8 feet square.	Records summarized in Engineering News, Feb. 29, 1912.
	do	Weather Bureau	July, 1916	Present	Floating pan, 10 inches by 4 feet, circular.	Published in Climatological Data—California Section; also Nevada Section.
18	Cortena rice field	University of California	1922	do	Pan	Records at division of irrigation, college of agriculture, Davis, Calif.
19	Davis	do	1911 (summer only).	1918 (summer only).	Specially designed tank, embedded in ground.	Do.
	do	do	Aug. 2, 1924	Oct. 3, 1924	Specially designed tank (moist soil).	Original records at engineering office, Bureau of Public Roads, Federal Building, Berkeley, Calif.
20	Point Reyes	Weather Bureau	July 21, 1910	Nov. 4, 1910	Evaporometer; 2 pans	Record unsatisfactory due to high winds.
21	Berkeley	University of California and U. S. Department of Agriculture.	1904	1905	Tanks set in ground	Results summarized in Experiment Stations Bulletin No. 177.
22	Oakdale (near)	South San Joaquin irrigation district and Weather Bureau.	Mar. 1, 1918	Present	Class A, Weather Bureau standard.	Published in Climatological Data—California Section.
	do	do	June 11, 1921	Sept. 25, 1921	Floating pan, 10 inches by 4 feet, circular.	Records at Weather Bureau Office, San Francisco, Calif. (not published).
23	Lake Eleanor	City and county of San Francisco	July, 1910	September, 1918	do	Records at office of water resources branch, U. S. Geological Survey, customhouse, San Francisco, Calif.
24	Dallas (and Warner) Reservoir.	Modesto irrigation district	1914	1914	Floating pan, 18 inches by 3 feet, square.	See Engineering News, Aug. 12, 1915.
25	Don Pedro Reservoir	Turlock and Modesto irrigation district.	Apr. 13, 1924	Present	Floating pan, 15 inches by 3 feet by 4 feet.	Records at office of Turlock irrigation district, Turlock, Calif.

[1] Atmometers are in use at a number of Forest Service stations but only 2 representative stations are listed.

	Station	Records made by—	Duration		Equipment	Remarks
			From—	To—		
26	Alvarado (near)	Leslie-California Salt Co. and Weather Bureau.	Aug. 1, 1924	Present	Class A, Weather Bureau standard.	Published in Climatological Data—California Section.
72	Calaveras Reservoir	Spring Valley Water Co	March, 1915	June, 1918	2 floating pans, 18 by 47 inches, circular, painted black.	Records in engineering department, Spring Valley Water Co., San Francisco, Calif.
28	Mountain View (near)	University of California	Sept. 1, 1921	Jan. 1, 1923	Tank, 3 by 3 feet, circular, embedded in ground.	Records at division of irrigation, college of Agriculture, Davis, Calif.
29	Delhi	do	Dec. 15, 1921	Oct. 15, 1928	do	Do.
30	Coyote (near)	Edwin Duryea, jr.	1904	1905	11 pans, 12 inches by 3 feet square.	Summarized in Engineering News, Feb. 29, 1912.
					No. 1, Weber Dam site (land)	
					No. 2, Lower Gorge (land)	
					No. 3, Bailey Avenue (land)	
					No. 4, Laguna Seca, north (land)	
					No. 5, Laguna Seca, west (land)	
					No. 6, Laguna Seca, west (floating).	
					No. 7, Laguna Seca, east (floating)	
					No. 8, San Felipe Dam (land)	
					No. 9, San Felipe Reservoir (land)	
					No. 10, Upper Gorge (land)	
					No. 11, Upper Gorge (floating)	
31	Bass Lake	San Joaquin Light & Power Corporation.	1912	Present	Floating pan, 18 inches by 3 feet, square.	Records at office of San Joaquin Light & Power Corporation, Fresno, Calif.
32	Huntington Lake	Southern California Edison Co	1917	1921	Floating pan	Engineering department, Southern California Edison Co. considers record unreliable.
33	Spreckels	Spreckels Sugar Co	1917	1918	Circular pan, 6 feet in diameter, on surface of ground.	Records private property.
34	Independence (near)	Charles H. Lee for city of Los Angeles.	August, 1908	May, 1911	Pan, 10 inches by 3 feet, square, on ground.	See Transactions American Society of Civil Engineers, Vol. LXXVIII (1915).
					Pan, 10 inches by 3 feet, square, floating.	
					Tank, 4 feet by 3 feet 6 inches, circular, embedded in ground.	
	Independence (near)	Do	June, 1910	May, 1911	Tanks, 6 feet 6 inches by 7 feet 5 inches, circular, embedded in ground (moist soil).	Do.
35	Soldier's Camp (near Lone Pine).	University of California and U. S. Department of Agriculture.	1905	1905	Tanks set in ground	See Office of Experiment Stations, Bulletin No. 177.
36	Owens Lake	Charles H. Lee for city of Los Angeles.	1905	1915	Owens Lake basin considered as an evaporation pan; results checked by evaporating Owens Lake brine in laboratory.	Summarized in Monthly Weather Review, February, 1924.
37	Kingsburg (near)	California State Engineering Department.	November, 1881	Octtober, 1885	Floating pan, 15 inches by 3 feet, square.	See Physical Data and Statistics, 1886, published by State of California.
					Pan, 15 inches by 3 feet, square, set 10 inches into ground.	
38	Tulare	University of California and U. S. Department of Agriculture.	1903	1905	Tanks set in ground (also moist soil).	Summarized in Office of Experiment Stations, Bulletin No. 177.
39	Trona	American Trona Corporation	Mar. 24, 1920	Oct. 1, 1920	Pan, 10 inches by 4 feet, circular, on surface of ground (also brine).	Records private property.
40	Little Bear Valley	Arrowhead Reservoir Co	March, 1895	May, 1897	3-foot pan floating in concrete basin, surrounded by 1 foot of water (also snow).	See Journal of Electricity and Western Industry, May 15, 1921.
41	Mount Wilson[1]	Forest Service	Indefinite period, summer only.	Indefinite period, summer only.	Porous cup atmometer (distilled water).	Records at office of U. S. Forest Service, Los Angeles, Calif.
42	Pasadena	California Institute of Technology	June 23, 1926	July 3, 1926	Tank, 5-foot, cubical; pan, 18 inches by 2 feet, square (both insulated).	See Physical Review October 1927, vol. 30, p. 527, and Bulletin No. 68, National Research Council.
43	Pomona (near)	University of California and U. S. Department of Agriculture.	1903	1905	Tanks set in ground	See Office of Experiment Stations Bulletin No. 177.
44	Riverside (Arlington Heights).	do	June 24, 1905	Sept. 29, 1905	do	Do.
	Riverside	Bureau of Plant Industry	Mar. 16, 1923	Present	Porous cup atmometer, (distilled water).	See (1) Ecology, Vol. VI, No. 3, July, 1925, (2) Phytopathology Vol. XV, No. 8, August, 1925. Records made on similar plan at Shafter, Watsonville (1925 only) and near Torrance, Calif. Unpublished records at office of cotton, truck, and forage crop disease investigations, Bureau of Plant Industry, Washington, D. C.
	do	Citrus Experiment Station	October, 1924	do	Similar to class A Weather Bureau standard except pan is 2 feet above ground.	Records at Citrus Experiment Station, Riverside, Calif.
45	Whitewater Ranch	Coachella Valley County water district.	January, 1920	January, 1921	Pan, 18 inches by 3 feet, circular, set 16 inches into ground.	Records private property.
46	Indio	Weather Bureau (auxiliary to Salton Sea experiments).	October, 1907	November, 1907	Pan, 6-foot, circular, on ground	See monthly Weather Review, February, 1910.
			July, 1908	November, 1908	Pan, 2-foot, circular, on 10-foot tower.	Do.
	do	United States date garden	Jan. 1, 1923	Present	Pan, 15 inches by 3 feet by 8 feet, on ground.	Records at United States date garden, Indio, Calif.
47	Mecca	Weather Bureau (auxiliary to to Salton Sea experiments).	July, 1908	November, 1908	Pan, 6-foot, circular, on ground	See monthly Weather Review, February, 1910.
					Pan, 2-foot, circular, on 10-foot tower.	
48	Salton Sea	Weather Bureau	June 14, 1909	Nov. 1, 1909	4 towers, with pans, 2, 4, and 6-foot, circular, at various heights above land and water.	Do.
49	Mammoth	Weather Bureau (auxiliary to Salton Sea experiments).	1907	1908	Pan, 6-foot, circular, on ground	Do.
					Pan, 2-foot, circular, on 10-foot tower.	Do.
50	Brawley	do	1907	1908	do	Do.
51	Calexico	University of California and U. S. Department of Agriculture.	1903	1905	Tanks set in ground	See Office of Experiment Stations Bulletin No. 177.

[1] Atmometers are in use at a number of Forest Service stations but only 2 representative stations are listed.

	Station	Records made by—	Duration		Equipment	Remarks
			From—	To—		
52	Mexicali, Mexico	Primera Zona de Irrigacion	July 13, 1923	Present	Zinc pan, 1.22 meters, circular, above ground.	Records available at office of Primera Zona de Irrigacion, Mexicali, Mexico.
53	Bard	Bureau of Plant Industry	1910	do	Tank, 30 inches by 6 feet, circular, embedded in ground.	See published reports of the work of the Yuma experiment farm.
54	Yuma, Ariz	University of Arizona and Weather Bureau.	July 1, 1917	do	Class A, Weather Bureau standard	Published in Climatological Data—Arizona Section.
55	Yuma, Ariz. (near)	do	September, 1920	do	do	Do.
56	San Luis Rey Valley	Geological Survey	1914	1915	Entire valley considered as an evaporation pan.	See Water Supply Paper No. 446, United States Geological Survey (1919).
57	Lake Hodges Dam	San Dieguito Mutual Water Co	1914	Present	Pan, 18 inches by 3 feet, square, set 12 inches into ground.	Now under control of City of San Diego, Calif.
58	Cuyamaca Reservoir	Cuyamaca Water Co	1913	do	Pan, 18 inches by 3 feet, square, set 16 inches into ground.	Records available at office of La Mesa, Lemon Grove and Spring Valley irrigation district, La Mesa, Calif.
59	Murray Reservoir	do	1912	January, 1928	Floating pan, 18 inches by 3 feet, square, submerged 12 inches.	Do.
60	Sweetwater Dam	Sweetwater Water Corporation	1889	1919	Floating pan, 18 inches by 3 feet, square.	Summary available at company office, National City, Calif.
61	Chula Vista	Western Salt Works and Weather Bureau.	Sept. 1, 1918	Present	Class A, Weather Bureau standard.	Published in Climatological Data—California Section.
62	Morena Dam	City of San Diego	November, 1915	do	Floating pan, 18 inches by 3 feet, square, submerged 16 inches.	Records in operating department, city hall, San Diego, Calif.
	do	do	August, 1925	do	Pan, 18 inches by 3 feet, square, embedded in ground.	Do.
63	Barrett Dam	do	August, 1923	do	Floating pan, 18 inches by 3 feet, square, submerged 16 inches.	Do.
	do	do	August, 1925	do	Pan, 18 inches by 3 feet, square, embedded in ground.	Do.
64	Upper Otay Dam	do	April, 1916	July, 1921	Floating pan, 18 inches by 3 feet, square, submerged 16 inches.	Do.
	do	do	August, 1925	Present	Pan, 18 inches by 3 feet, square, embedded in ground.	Do.
65	Lower Otay Dam	do	{November, 1915 {August, 1920	December, 1915 Present	Floating pan, 18 inches by 3 feet, square, submerged 16 inches.	Do.
	do	do	August, 1925	do	Pan, 18 inches by 3 feet, square, embedded in ground.	Do.

551.590.2 : 551.570.4

NOTES, ABSTRACTS, AND REVIEWS

Anders Ångström on the atmospheric transmission of sun radiation and on dust in the air,[1] *by H. H. Kimball.*—The author remarks that the overwhelming interest of Smithsonian Institution investigators in variations in the solar output of radiant energy is perhaps responsible for the comparatively slight use that has been made of their valuable data on atmospheric transmission in detailed studies of the way in which the atmosphere acts on the radiation that penetrates it. For example, during the years 1923–1928, while the range from minimum to maximum in the annual mean values of the solar constant has been only about 0.5 per cent, the range in corresponding annual amounts of solar radiation reaching the surface of the earth at Stockholm has been 25 per cent.

Three general ways in which the atmosphere depletes radiant energy passing through it are given as follows:

(1) Selective absorption by the gases of the atmosphere.
(2) The scattering or diffusing effect of the atmosphere.
(3) The scattering by atmospheric dust.

The loss by reflection from cloud surfaces is not here considered.

The major part of the loss by selective absorption is due to the absorption in the infra-red part of the spectrum by water vapor, the relation of which to surface water-vapor pressure has been determined by Fowle. Likewise, the scattering by gas molecules may be computed by means of Rayleigh's equations as modified by King.

The law of the scattering of radiant energy by atmospheric dust is not so well known. The expression for scattering by gas molecules contains the expression $\frac{1}{\lambda^4}$, where λ is the wave length of the radiant energy. It has generally been assumed that scattering by dust is independent of the wave length, but since dust particles vary greatly in size, Ångström concludes that in the expression for scattering by dust the exponent of λ must be greater than 0 and less than 4, and that the scattering may be expressed by $\gamma = \frac{\beta}{\lambda^\alpha}$.

From computed values of the transmission for dust-free air for wave lengths free from selective absorption, and observed values of the transmission at different places for the same wave lengths, Ångström computed the values of α and β given in Table 1.

TABLE 1.—*Data on scattering of solar radiation by dust*

Stations	Altitude above sea-level	Average conditions		Haziest days for August, 1921		Authority
		β	α	β	α	
	Meters					
Washington	35	0.098	1.24			Smithsonian Institution.
Upsala	35	(.090)	(.70)	0.362	0.515	Lindholm, 1912.
Bassour	1,160	.031	1.22	.255	.53	Smithsonian Institution.
Hump Mountain	1,500	.031	1.33			Do.
Mount Wilson	1,780	.018	1.26	.205	.70	Do.
Calama	2,250	.023	1.33			Do.

The author points out that β is the scattering by dust for radiation at $\lambda = 1$ micron without regard to the value of α. Also, if the depletion due to scattering by dust were independent of λ, α should equal zero. Actually, however, Table 1 shows that under average conditions α varies but little from 1.28 over a wide geographical range, and at widely different altitudes, and that the haze caused by the eruption of Katmai Volcano in June, 1912, increased the value of β about tenfold, and greatly reduced the value of α.

From the values of α in Table 1 it appears that the size of the dust particles is independent of height above

[1] Geografiska Annaler 1929, H. 2.